Acoustic Scattering by Shell-Covered Seafloors

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LONG-TERM GOALS

To understand the acoustic reverberation properties of the seafloor when benthic shells are present. Quantitative characterization of these properties will lead to improved capability in predicting sonar performance and use of sonars in the mapping of benthic shells.

OBJECTIVES

To understand the physics of acoustic scattering by benthic shells. Realistic acoustic scattering models of various important classes of these complex scatterers will be developed and applied to at-sea experiments and surveys involving high frequency acoustic sonars.

APPROACH

Benthic shells are in the broad acoustic category of complex finite-sized shapes for which there is no exact mathematical solution to describe the acoustic scattering. Subsequently, the research program is a combination of theoretical analysis, numerical simulations, laboratory experimentation at WHOI, and comparison between models developed in this program and scattering data collected at sea. A crucial aspect of describing the scattering requires understanding the precise shape of the target. Measurements of the shape are made through use of medical computerized tomography using the WHOI CT facility. The theoretical analysis involves taking into account scattering by the surface of the shells as well as sharp edges which may, under some conditions, dominate the scattering. The

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14. ABSTRACT
To understand the acoustic reverberation properties of the seafloor when benthic shells are present. Quantitative characterization of these properties will lead to improved capability in predicting sonar performance and use of sonars in the mapping of benthic shells.

15. SUBJECT TERMS

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laboratory experiments are principally in the backscatter configuration, although some forward scattering measurements are to be made. The measurements are in the 40-95 kHz frequency range using a broadband chirp signal. A computer-controlled stepper motor is used to rotate the shells so that the scattering can be measured over all angles of orientation (in one plane) in one-degree increments. Both spectral and time domain (through pulse compression) analyses are conducted. The models are to be initially compared with the laboratory data for refinement, and then incorporated into a generalized seafloor scattering model for comparison with data collected at sea. The ocean data are from the ONR SAX99 experiment off the west coast of Florida, as well as from an experiment involving sand dollars planned to take place near Humboldt Bay, California. The shells used in the laboratory measurements (and associated CT scans) are the same as those used in the SAX99 experiment and similar to those expected to be surveyed near Humboldt Bay. Tim Stanton oversees the entire program, and is leading the laboratory experiments and model development of the scattering by individual shells. Greg Crawford will be conducting the field experiment near Humboldt Bay and Anatoliy Ivakin will be incorporating the shell scattering models into his generalized seafloor scattering model. All three PI's will be involved in comparing the models with the at-sea measurements. Also, Dezhang Chu (WHOI) plays a key role in the laboratory and modeling work and Andone Lavery (WHOI) oversees the CT scans.

WORK COMPLETED

Three major tasks were completed in this first year of the grant. The tasks were principally focused on model development and preparations for laboratory experimentation.

1*) Model Development*. One key aspect of the scattering involves the edges of the shells. An existing approximate formulation, based on the Biot-Tolstoy exact solution to infinitely long straight edges, was adapted for scattering by flat circular disks for a wide range of oblique scattering angles. Given the approximate nature and associated limitations of this formulation, the results will be compared with the laboratory data involving machined metal disks for possible modification, once the data are collected. The model will then be subsequently extended to account for the shapes of shells.

2) *Medical CT Scans*. Computerized tomography scans were made on 51 shells using the WHOI CT facility (measurements funded through an internal WHOI grant using private money). Most of the shells were from the SAX99 experiment, while three were from near Humboldt Bay. All shells were categorized according to their size and species. 3-10 shells per species, spanning the full range of sizes, were scanned with the CT machine. Full, three-dimensional renderings of the shells have been made (including internal structures of the sand dollars) (Fig. 1).

3) *Laboratory Experimentation.* Preparations were made for the planned extensive measurements to be made in year two of the grant. Mechanical supports for the transducers were constructed, which would allow for efficient production-style measurements of the scattering by the many shells. The system was calibrated and preliminary broadband backscattering measurements were made of a scallop shell and a flat circular metal disk of a similar outer dimension. Polar plots of the scattering have been produced indicating the strong directional behavior of the scattering of the objects. Also, the broadband signals were temporally compressed to illustrate resolved scattering highlights of the targets.

RESULTS

Although the measurements in this first year are at the preliminary stage, we demonstrated the significant departure of the scattering between the simply shaped flat disk and the actual benthic shell. While this difference is not a surprise, it is a first demonstration of the phenomenon involving this category of scatterer and provides the first quantification of the complex nature of the scattering by these benthic shells.

IMPACT/APPLICATIONS

The potential for impact and application of the results of this project are significant. Shells are potentially significant sources of scattering (and associated attenuation) of sound, especially when occurring in dense layers. The results of this project can help to quantify the complex nature of the scattering for various conditions, resulting in improvements in sonar performance predictions as well as providing for a quantitative tool for studying beds of shells.

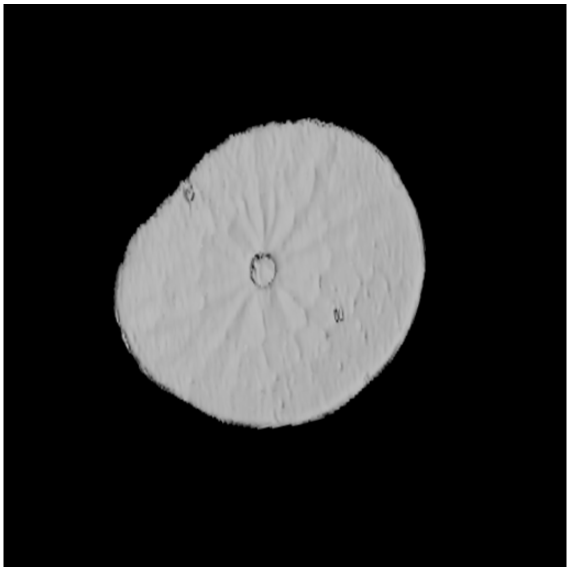
TRANSITIONS

None.

RELATED PROJECTS

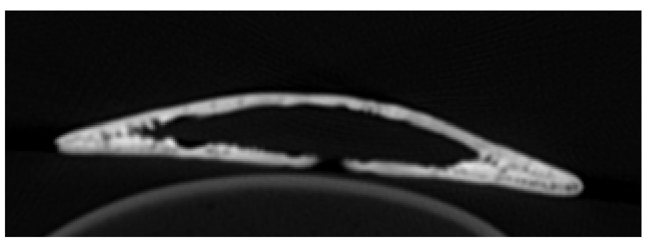
The methods in this project are related to two other projects: 1) Acoustic scattering classification by zooplankton and microstructure (funded by another grant by ONR) and 2) Measurements and modeling of acoustic scattering by fish (funded by another grant by ONR and NOAA). This project takes advantage of the hardware and methodologies developed principally in (1) above, and to some extent, in (2).

SAND DOLLAR CT IMAGES



Bottom View

Top View



Side View of Slice Through Middle

Figure 1. Medical computerized tomography (CT) scan of sand dollar using WHOI CT facility. The three-dimensional information on shape derived from these data, as well as from scans from 50 other shells, will be used as input into advanced acoustic scattering models to be developed in this project.